able treatment alternative for difficult vascular lesions of the central nervous system.

Highly specific treatment can be administered, including but not limited to the instillation of pharmacologic agents, the injection of particulate embolic substances or glue embolization, the release of detachable microcoils, the inflation of detachable and nondetachable balloons, or a combination of these agents. This less-invasive therapy often allows patients to be discharged from hospital within three days. Some patients require several sessions of therapy, which may be spread out over a period of weeks. Other patients need only a single session. Patients undergoing endovascular therapy are usually selected because they are poor surgical risks or are those in whom conventional neurosurgical techniques are likely to be unsuccessful. As endovascular techniques improve with evolving technology and experience, endovascular therapy will likely become the prime mode of therapy for certain indications.

Intracranial aneurysms can be treated by endovascular occlusion of the aneurysm itself or its feeding artery. This offers the benefits of continuous monitoring of the patient's neurologic status during the procedure, the avoidance of general anesthesia and brain retraction, and immediate high-quality angiography for verification of the procedure's success. For these reasons, several centers have been actively pursuing coil embolization of aneurysms. Small microcoils are pushed through a microcatheter into the aneurysm itself until the aneurysm sac is virtually filled. This may require the placement of multiple coils of varying sizes and configurations. The coils are detached either mechanically or electrolytically. Pitfalls include incomplete thrombosis of the aneurysm, difficulties in access, unintentional aneurysmal rupture or vascular damage, thrombosis of normal adjacent vessels, and ischemic complications. Long-term follow-up for these patients is required. Further research is ongoing, but it is clear that this technique holds great promise.

Intracranial arteriovenous malformations are well suited to endovascular techniques. Surgical access may be difficult or impossible, and some lesions are too large for effective focused radiotherapy. To select patients suitable for treatment, we analyze angiographic risk factors predisposing to bleeding and "steal" symptoms. Endovascular embolization is especially useful as an adjunct to conventional neurosurgical and radiosurgical procedures. Advantages include continuous neurologic monitoring of awake patients, the ability to test vascular territories using intra-arterial administration of amobarbital, and the staged obliteration of the larger malformations to minimize altered hemodynamics. Microcatheters are maneuvered into the feeding arterial pedicles of the arteriovenous malformations, and a rapidly polymerizing cyanoacrylate liquid adhesive is administered to thrombose the arteriovenous malformations. Many pedicles can be devascularized in one session, but the larger malformations require several sessions. A few intracerebral arteriovenous malformations may be cured by this technique, and in most lesions the size of the lesion and blood flow are substantially reduced. Limitations of the procedure are related to vascular access problems, the location of the feeding vessels in critical contiguous areas, and the risks of induced hemorrhage or infarction. In more than 100 such procedures, results have been encouraging, with long-term follow-up continuing.

Symptomatic vasospasm after subarachnoid hemorrhage is still a challenge in neurosurgical management. Endovascular treatments include mechanical dilatation of the vasospastic areas using balloon angioplasty. This technique can be used to reach lesions in large arteries of the circle of Willis. Associated problems include possible aneurysmal rupture if the aneurysm has not already been treated, worsening ischemic changes leading to infarction, and difficulty of access to the narrowest distal arterial branches and perforators, which may be responsible for the ischemic symptoms. The endovascular treatment of vasospasm using pharmacologic agents such as intra-arterial papaverine hydrochloride and other agents may also prove useful. The long-term effects of intracranial angioplasty and pharmacologic treatment of vasospasm are not known and remain a worthwhile avenue of inquiry.

Perhaps the most exciting and rapidly developing indication for endovascular techniques in the cerebral circulation is that of thrombolytic therapy for acute occlusive stroke. While trials of intravenous thrombolytic therapy are taking place at major medical centers, the ability to selectively administer thrombolytic and neuroprotective agents may render our present "treatment" of acute stroke obsolete. Direct intra-arterial administration of urokinase, a thrombolytic agent, into the acutely occluded basilar and carotid vessels has had some success. The results of our limited experience using intra-arterial tissue plasminogen activator to lyse thromboembolic material in the acute stages of stroke appear promising. Far more work needs to be done, but the benefits could be enormous.

Interventional endovascular therapy for cerebrovascular disease has already had important effects. Certain limitations exist, and open microsurgical techniques and stereotactic radiosurgery remain mainstays of treatment in the foreseeable future. Nonetheless, with further technical advances and clinical experience, endovascular therapy for disorders in the central nervous system can be expected to flourish.

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Preventive Aspects of Helmet Safety

HELMET USE HAS BEEN SHOWN to be effective in reducing the extent of injury in both motorcycle and bicycle accidents. Motorcycle helmet use reduces the incidence of severe head injuries by 50%, regardless of the speed limit. After repeal of Kansas's helmet law, the incidence of head injuries increased by 70%, with helmetless motorcyclists at an 81% greater risk of serious injury. In 1990 bicycle helmet use became compulsory in Victoria, British Columbia. It resulted in a marked reduction in the number of hospital admissions of injured cyclists and in the proportion of head injuries compared with the previous year.

In 1974 Congress repealed the US Secretary of Transportation's right to influence states to enforce helmet laws. Ar-

guments to repeal mandatory helmet laws include an infringement on personal rights, the increased rate of accidents due to visibility and hearing limitations (not shown to be true), helmet weight contributing to the severity of injury (not shown to be true), and a lack of proof of effectiveness in preventing injury (not true). Full-coverage helmets have been shown to reduce horizontal peripheral vision by only 3%. Furthermore, a noise loud enough to be heard over the baseline noise of the motorcycle can easily be heard by a helmeted rider.

Research into the construction of helmets has resulted in improved effectiveness and comfort over the cork-lined helmets used during the World War II era. An effective helmet has a plastic or fiberglass rigid shell with a chin strap and an energy-absorbing foam liner. Most impacts to helmets in both motorcycle and bicycle accidents occur on the front and sides with infrequent penetration injuries.

Motorcycle helmet standards are reasonably consistent from country to country. In general the helmet should protect the victims from an impact velocity of 6 to 7 m per second or about 20 to 25 km per hour. These figures are reasonable because 75% of motorcycle injuries occur at less than 48 km per hour. Only in Great Britain is there a standard for faceguard or chin-strap impact testing. The protective properties of the face guard at other than low-velocity impacts remain controversial.

A stiffer shell results in diffusion of the impact and in a rebound of the energy transmission. The protective characteristics of the foam liner depend on the impact velocity. Stiffer foam is more effective at high velocities, whereas a less stiff foam provides more protection at low velocity. Increasing the thickness of the liner leads to a better level of protection at higher velocities but may also increase user discomfort due to the increased mass and weight of the helmet.

Standards for bicycle helmets changed in 1990. The penetration test was replaced by resistance testing to localized loading, thereby allowing the use of soft-shell helmets. In laboratory and field testing, the effectiveness of both the hard-shell and soft-shell helmets was comparable.

Researchers continually strive to construct helmets that offer optimum protection and comfort. The best helmet made is worthless if it sits on the shelf, however.

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Care of Patients With Aneurysms

THE SURVIVAL OF PATIENTS with untreated ruptured cerebral aneurysm is poor. By contrast, surgical treatment is clearly beneficial. It is imperative, however, to make the diagnosis of subarachnoid hemorrhage as soon as possible. The initial bleeding event is often missed. It can be mild, but a subsequent hemorrhage is often devastating if not fatal. Middle-aged patients who present with a severe headache, frequently described as "the worst headache of my life," with or without neck stiffness must be suspected of having subarachnoid hemorrhage, particularly those with hypertension or atherosclerosis. Many patients are misdiagnosed as having flu or other viral illness, migraine (which only rarely starts late in life), or tension headache. Lumbar puncture, computed tomographic (CT) scan, or both will settle the issue in most cases. More severe subarachnoid hemorrhage resulting in mental obtundation with or without neurologic deficit is not usually a diagnostic problem.

The treatment of subarachnoid hemorrhage is surgical in most cases. Traditionally the operation has been done after a waiting period of two weeks to allow the swelling and vasospasm to resolve. The outlook for those patients who improved during that two-week period was excellent. Overall management results, however, indicate that 60% of the patients die or are disabled as a result of rebleeding or vasospasm during that period of waiting. Numerous therapeutic strategies have been developed to manage these complications, including early surgical intervention.

Prospective studies indicate that rebleeding occurs in more than 20% of patients in the first two weeks after the initial bleeding event, with a peak incidence in the first 24 to 48 hours. Mortality associated with a second hemorrhage is high (70% to 80%). Only obliteration of the aneurysmal sac can predictably avert this occurrence. Antifibrinolytic agents, such as aminocaproic acid (Amicar), reduce the incidence of rebleeding but increase the incidence of ischemia and stroke. Induced hypotension has similar deleterious effects. Ischemic deficits from vasospasm develop in a third of patients surviving the initial bleeding event and leave them disabled. While the exact pathophysiology of vasospasm is unclear, the amount of blood in the subarachnoid cisterns predicts the severity of the vasospasm. Induced hypervolemia and hypertension, as well as the use of calcium channel blockers, are now routinely used to combat the effects of vasospasm, but success is only modest. Transcranial Doppler studies and single photon-emission CT scanning can be useful guides to the evolution and severity of vasospasm.

With recent advances in neuroanesthesia, pharmacologic cerebral protection, intraoperative monitoring, and microsurgical instrumentation and techniques, neurosurgeons at a number of centers are turning to early surgical interventions. This is an effort to avert death from spontaneous rebleeding and to protect against rebleeding as a complication of the induced hypertension and hypervolemia used to treat vasospasm. Furthermore, preliminary experience with angioplasty, which can help ameliorate vasospasm in selected patients, indicates that it may be safer following aneurysm obliteration.

Several reports, including the International Cooperative Study on the timing of aneurysm surgery, have documented good results from early surgical intervention. There appears to be an advantage to early surgical treatment in patients who are in good neurologic condition on admission. There are no compelling data on poorer grade patients to recommend early operation, but anecdotal reports suggest that early surgical treatment and aggressive medical management may yield a better result in these patients as well. Other benefits of this treatment include the early removal of intracerebral hematomas, fewer medical complications, probably a lowered incidence of the hydrocephalus that may follow subarachnoid hemorrhage, less psychological stress for the patient and the family, and probably a shorter hospital stay. A somewhat higher operative morbidity and mortality must be accepted